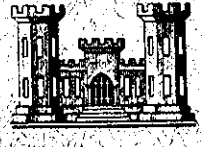
HURRICANE SURVEY

INTERIM REPORT

WESTPORT

CONNECTICUT



U.S. Army Engineer Division, New England
Corps of Engineers
Waltham, Mass.

31 March 1961

TABLE OF CONTENTS

TABLES

PLATES

ATTACHMENTS

APPENDICES

(Bound in separate volume)

SYLLABUS

The Division Engineer finds that a serious problem of tidal flooding from hurricanes and other severe storms exists in the town of Westport, Connecticut. The acuteness of the problem is indicated by the fact that three severe hurricanes and several other great storms have struck the area within the past 22 years and upon their recurrence would cause total flood damages of nearly $4,000,000 at 1960 prices. In the Compo Beach area of Westport, damages of $290,000 would be sustained in the event of a recurring hurricane of 1938 magnitude. The average annual damages from tidal flooding at Westport, to and below an elevation of 13.6 feet msl, amount to $187,000. This includes $50,000 in the Compo Beach area.

The Division Engineer recommends the construction of a dike to provide protection to the residential area in the Compo Beach section of Westport against a future tidal-flood stage equal to the record level of 10.5 feet msl experienced in the 1938 hurricane. This is the maximum degree of protection acceptable to local interests. The estimated first cost of the plan is $310,000, of which $217,000 is to be borne by the United States and $93,000 by local interests. The benefit to cost ratio is 2.4 to 1.0.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

)RESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

NEDGW

31 March 1961

SUBJECT: Interim Report on Hurricane Survey, Westport, Connecticut

TO: Chief of Engineers
Department of the Army
Washington, D. C.
ATTENTION: ENGCW-P

AUTHORITY

1. This report is submitted in compliance with Public Law 71, 84th Congress, 1st Session, approved 15 June 1955, which reads as follows:

> "Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in view of the severe damage to the coastal and tidal areas of the eastern and southern United States from the occurrence of hurricanes, particularly the hurricanes of August 31, 1954, and September 11, 1954, in the New England, New York, and New Jersey coastal and tidal areas, and the hurricane of October 15, 1954, in the coastal and tidal areas extending south to South Carolina, and in view of the damages caused by other hurricanes in the past, the Secretary of the Army, in cooperation with the Secretary of Commerce and other Federal agencies concerned with hurricanes, is hereby authorized and directed to cause an examination and survey to be made of the eastern and southern seaboard of the United States with respect to hurricanes, with particular reference to areas where severe damages have occurred.

"SEC. 2. Such Survey, to be made under the direction of the Chief of Engineers, shall include the securing of data on the behavior and frequency of hurricanes, and the determination of methods of forecasting their paths and improving warning services, and of possible means of preventing loss of human lives and damages to property, with due consideration of the economics of proposed breakwaters, seawalls, dikes, dams, and other structures, warning services, or other measures which might be required."

SCOPE OF SURVEY

2. SCOPE

This interim report of survey scope presents the results of an investigation of hurricane and other storm-induced tidal flooding in the town of Westport, Connecticut. It is one in a series of reports which, when completed, will constitute a survey of the entire Atlantic and Gulf coastal areas of the United States subject to tidal flooding occasioned by hurricanes.

This report includes data on climatology, hydrology, and tidal-flood damages; a summary of the historical occurrences of hurricanes and other severe storms; and a description, together with estimates of costs and benefits, of a recommended plan of improvement which will provide protection against tidal flooding.

Field work has consisted of flood damage investigations, topographic and hydrographic surveys in the area of considered protective works, and subsurface investigations to determine the nature and characteristics of underlying material.

3. COORDINATION

State officials and local interests have been consulted frequently during the course of the study and the work has been coordinated and discussed with appropriate Federal agencies. The views of local interests have been considered in arriving at a practicable and economic means of providing needed protection.

A public hearing has been held at Westport to acquaint all interested parties with the recommended plan of protection and to obtain their views and comments thereon. Coordination with other agencies is discussed in further detail in paragraph 73.

PRIOR REPORTS

4. HURRICANE REPORTS

There are no previous reports by the Corps of Engineers on the specific subject of hurricane protection for the town of Westport. Part Two, Chapter XXXIX (unpublished) of the report (Senate Document No. 14, 85th Congress, 1st Session), on the "Land and Water Resources of the New England-New York Region," prepared by the New England-New York Inter-Agency Committee, pursuant to Presidential directive of October 9, 1950, includes a brief history of hurricane occurrences in New England, a description and summary of experienced losses in recent hurricanes, and a discussion of several methods of reducing damages.

5. NAVIGATION REPORTS

Westport Harbor and the Saugatuck River have been the subject of a number of navigation reports since 1827. The following three reports, prepared and published since 1891, form the basis for the existing navigation project:

a. House Executive Document No. 179, 51st Congress, 2nd Session, 1891.

b. House Document No. 67, 54th Congress, 1st Session, 1896.

c. House Document No. 448, 81st Congress, 2nd Session, 1950.

6. BEACH EROSION CONTROL REPORTS

Three reports have been prepared and published which cover the subject of beach erosion in the town of Westport.

a. House Document No. 239, 74th Congress, 1st Session, contains a report on a cooperative beach erosion control study of Compo Beach in Westport. It recommends the construction of a breakwater and placement of sandfill by local interests.

b. House Document No. 454, 81st Congress, 2nd Session, containing a beach erosion control study on Area 1, Ash Creek to Saugatuck River, Connecticut, recommends that the United States adopt projects authorizing Federal participation in the construction of protective works at a number of Connecticut coastal areas, including three in the town of Westport. The report also suggests the accomplishment by local interests of three projects for the improvement of privately owned shores in Westport.

c. House Document No. 174, 85th Congress, 1st Session, contains a beach erosion control study on Areas 8 and 11, Saugatuck River to Byram River, Connecticut. This report discusses the erosion problems along the Westport shore west of the Saugatuck River. It recommends no works of improvement in Westport.

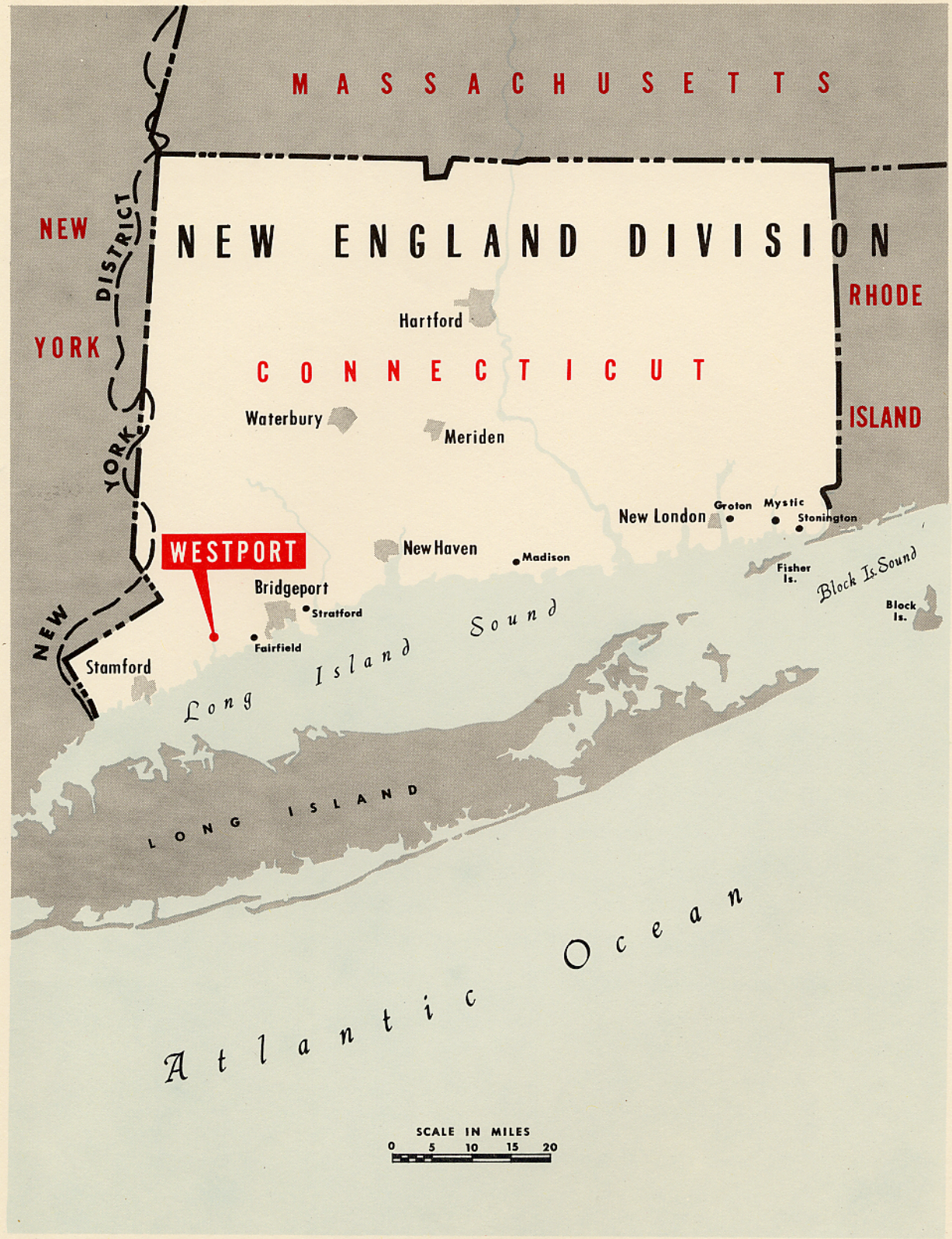
DESCRIPTION

7. LOCATION AND EXTENT OF AREA

The town of Westport, Connecticut, is located in Fairfield County, on the north shore of Long Island Sound, approximately 40 miles northeast of New York City and 10 miles southwest of Bridgeport, Connecticut. It is adjacent to the town of Fairfield on the east and the city of Norwalk on the west. Westport covers an area of about 20 square miles and has a total shoreline of approximately 10 miles along the Sound, including the lower two-mile reach of the Saugatuck River.

8. SHORE AREA

The Westport shore extends in a general westerly direction about 4.5 miles from the mouth of Sasco Brook, the eastern boudary of the town, to Cedar Point on the left or east bank at the mouth of the Saugatuck River. Opposite Cedar Point, on the right bank of the river, is Seymour Point and from this point the Westport shoreline continues westerly about one mile to the



U.S. Army Engineer Division, New England
Corps of Engineers
Waltham, Mass.

LOCATION MAP

Norwalk city line. The principal features along the Westport shore, from east to west, are (1) the Greens Farms area, an area of low glacial hills that run down to the waterfront, (2) Alvard and Elmwood Beaches, to the east and west of Sherwood Point, at Sherwood Island State Park, (3) the Compo Cove area, including the water frontage of the Compo Mill Beach Association on the east shore of the cove and Old Mill Beach on the west shore, (4) Compo Beach, immediately east of Cedar Point, and (5) Saugatuck Shores, a low-lying, sandy and marshy area west of Seymour Point.

9. HARBOR AND COASTAL STREAMS

The principal waterway in the town of Westport is Westport Harbor and Saugatuck River in the western part of the town. At the eastern boundary of the town is Sasco Brook.

a. Westport Harbor and Saugatuck River. The Saugatuck River rises in the north central part of the town of Redding, Connecticut, and flows in a general southerly direction about 25 miles to its mouth at Long Island Sound. It drains an area of 92 square miles and has a total fall of about 570 feet. The lower 4.2 miles of the river are navigable, from its mouth to the State Highway bridge at the main business center of the town. This portion of the river, known as Westport Harbor, has a width of about 3,700 feet at its mouth between Cedar Point on the east and Seymour Point on the west. Going up the river, the width decreases to about 1,300 feet at a point about 1.2 miles upstream, just below Stony Point, and then averages about 500 feet for the next three miles to the head of navigation. Westport Harbor has been improved for navigation. See paragraph 49.

b. Sasco Brook. This brook rises in the northwestern part of Fairfield, south of Hemlock Reservoir, and flows in a general southerly direction to its mouth at Long Island Sound. The brook has a drainage area of 9.5 square miles and a total fall of about 330 feet in its 14.5-mile length. The lower two miles of the brook form the boundary between the towns of Fairfield and Westport.

10. TIDES

The mean range of tide at Westport, at the mouth of the Saugatuck River, is 7.0 feet, from 3.8 feet above to 3.2 feet below

mean sea level. Spring tides have an average range of 8.3 feet and a maximum range of about 10.3 feet. A high spring tide will reach an elevation of about 8.8 feet above mean low water (5.6 feet above mean sea level). The time interval for a complete tidal cycle averages about 12 hours and 25 minutes. This results in the daily occurrence of two low and two high waters on an average of six out of every seven days. Hurricane tides, which in the recent past have reached a maximum elevation of 10.5 feet above mean sea level at the mouth of the Saugatuck River and in the Compo Beach area, are discussed in paragraph 35 of this report.

11. GEOLOGY

Westport is located on the seaboard lowland of the New England physiographic province. The town comprises most of the watershed of the tidal portion of the Saugatuck River which relieves a portion of the coastal area between the Housatonic and Hudson River basins. A maximum elevation of about 300 feet above mean sea level occurs in the northeastern part of the town. The maximum elevation west of the Saugatuck River is approximately 200 feet above mean sea level at a location about one mile northwest of the main business district. Bedrock, consisting of schist ridges trending north northwest-south southeast, alternating with more rounded granitic gneiss hills, is exposed or thinly covered by glacial till throughout much of the area. Notable exceptions are a large terrace in the north-central part of the town and a smaller terrace comprising much of the shopping district on the east bank of the Saugatuck River about 4.5 miles above its mouth. The terraces consist of stratified sand and gravel and are of fluvio-glacial origin.

12. AREA MAPS

Westport is shown on standard quadrangle sheets of the U. S. Geological Survey at a scale of 1:31,680 and on quadrangles of the U. S. Army Map Service at a scale of 1:25,000. The Westport shoreline, including Westport Harbor and the navigable portions of the Saugatuck River, are shown on U. S. Coast and Geodetic Survey Charts Nos. 220, 221, and 1213. A map of the area is included as Plate 1 of this report.

ECONOMIC DEVELOPMENT

13. POPULATION

The population of Westport, according to the Federal census of 1960, is 20,955. This represents a gain of about 80 percent since 1950 and nearly 155 percent since 1940. This increase in population has been due principally to the development of Westport as a residential suburb of nearby urban centers of employment. With the continued development of Fairfield County as a residential suburb of nearby metropolitan areas, including New York City, it is anticipated that the rate of population increase in Westport will continue to be high.

14. INDUSTRY

Manufacturing is of small consequence in the economy of Westport. There are approximately 20 manufacturing plants located within the town. They employ about 400 people. Over one-half of this work force is employed by three concerns. The principal manufactured products include wax and cleaners, wood office equipment, embalming fluids, and table tennis balls. Other activities include woodworking, the production of metal products and textile goods, and the operation of boat yards.

15. POWER

There are no public utility power plants in the town of Westport. The town is served by plants of the Connecticut Light and Power Company with main office at Berlin, Connecticut.

16. AGRICULTURE

Agriculture is quite limited in the town and is of no consequence in the areas inundated by tidal flooding.

17. NAVIGATION

The commerce in Westport Harbor and the Saugatuck River has averaged nearly 22,000 tons annually for the 10-year period from 1949 to 1958, inclusive. Seventy-seven percent of this commerce was sand and gravel and the remainder was petroleum products. The average annual tonnage figure of 22,000 reflects a figure of 90,000

ECONOMIC DEVELOPMENT

13. POPULATION

The population of Westport, according to the Federal census of 1960, is 20,955. This represents a gain of about 80 percent since 1950 and nearly 155 percent since 1940. This increase in population has been due principally to the development of Westport as a residential suburb of nearby urban centers of employment. With the continued development of Fairfield County as a residential suburb of nearby metropolitan areas, including New York City, it is anticipated that the rate of population increase in Westport will continue to be high.

14. INDUSTRY

Manufacturing is of small consequence in the economy of Westport. There are approximately 20 manufacturing plants located within the town. They employ about 400 people. Over one-half of this work force is employed by three concerns. The principal manufactured products include wax and cleaners, wood office equipment, embalming fluids, and table tennis balls. Other activities include woodworking, the production of metal products and textile goods, and the operation of boat yards.

15. POWER

There are no public utility power plants in the town of Westport. The town is served by plants of the Connecticut Light and Power Company with main office at Berlin, Connecticut.

16. AGRICULTURE

Agriculture is quite limited in the town and is of no consequence in the areas inundated by tidal flooding.

17. NAVIGATION

The commerce in Westport Harbor and the Saugatuck River has averaged nearly 22,000 tons annually for the 10-year period from 1949 to 1958, inclusive. Seventy-seven percent of this commerce was sand and gravel and the remainder was petroleum products. The average annual tonnage figure of 22,000 reflects a figure of 90,000

tons in 1956 when 88,000 tons of sand and gravel for road construction purposes were landed at Westport. Excluding the year 1956, the average annual tonnage of commerce in the harbor has equalled approximately 14,000 tons. During the boating season the harbor and river are used extensively by recreational craft ranging in size from small motor boats to large yachts up to 100 feet in length and 7 feet in draft.

A commercial wharf, 300 feet long, with facilities for handling of bulk material, including petroleum products, is located on the right bank of the river at the village of Saugatuck about 2-3/4 miles above the mouth of the river. Several boat yards and a number of private wharves are located along the navigable portion of the river above Saugatuck. A town wharf, for the accommodation of pleasure craft, is situated in the Cedar Point Yacht Basin on the left bank of the Saugatuck River near its mouth.

18. TRANSPORTATION

Westport is served by a network of modern highways. The Boston Post Road, U. S. Route 1, passes through the main business center of the town about two miles inland from the shore. Also running through the town in an east-west direction are the newly constructed Connecticut Turnpike and State Route 136, both located about one mile inland, and the Merritt Parkway, Connecticut Route 15, about four miles inland. A number of highways, including Connecticut Routes 33 and 57, connect Westport with points to the north. Rail transportation, both passenger and freight, is provided by the shoreline route of the New York, New Haven and Hartford Railroad. This line connects Westport with other coastal cities and towns in Connecticut, the city of New York to the west, and the cities of Providence, Rhode Island, and Boston, Massachusetts, to the east. Regularly scheduled airline service is available from the Bridgeport Municipal Airport in the town of Stratford, approximately 15 miles to the east.

19. RECREATION

The waters of Long Island Sound adjacent to Westport provide excellent facilities for bathing, boating, and fishing which are among the principal recreational activities of the area. The town maintains public beach facilities at Burial Hill Beach, west of Frost Point, and at Compo Beach. Other town-owned beaches, but without facilities,

are Canal Beach at the eastern end of the Westport shoreline and Old Mill Beach located just west of the inlet to Sherwood Pond. Bathing, boating, and picnicking facilities are available at Sherwood Island State Park which occupies about 6,000 feet of shoreline. The town has recently acquired ownership of the Longshore Country Club on the east bank of the Saugatuck River, a short distance above its mouth. This club, including an 18-hole golf course, will be publicly maintained and operated for general recreational purposes.

20. POLLUTION

Storm sewer systems are provided within the town. At the present time sanitary sewage treatment consists of individual septic tanks. A modern sewage treatment plant is under construction on the east bank of the Saugatuck River between the main line of the New York, New Haven, and Hartford Railroad and the Connecticut Turnpike. The effluent is to be discharged into the Saugatuck River after proper treatment in accordance with regulations of the Connecticut State Department of Public Health and the State Water Resources Commission.

21. FISHERIES

There is no sport fishing of any consequence in the immediate area of Westport Harbor and the Saugatuck River. In the offshore waters of Long Island Sound, numerous species of fish are found and there is considerable fishing activity especially during the summer season.

CLIMATOLOGY

22. CLIMATE

The Westport area has a temperate, changeable climate marked by four distinct seasons which are characteristic of New England. Owing to the moderating influence of Long Island Sound and the Atlantic Ocean, and particularly the variable movements of high and low pressure systems approaching from the west or southwest, extremes of either hot or cold weather are rarely of long duration. Coastal storms in the winter frequently bring rainfall in contrast to snow in the more northerly areas of New England. The prevailing winds are northwesterly in the winter and southwesterly in the summer.

High winds, heavy rainfall, and abnormally high tides occur with unpredictable frequency. Hurricanes can be expected especially during the months of August, September, and October.

23. TEMPERATURE

The average annual temperature in the Westport area, based on a 67-year record (1893-1959) at Norwalk, just west of Westport, is approximately 50°F. Average monthly temperatures at Norwalk, during the record period, vary from 27.7°F in January to 72.2°F in July. Recorded extremes have ranged from a minimum of -22°F to a maximum of 104°F. The mean, maximum, and minimum monthly temperatures at the U. S. Weather Bureau Cooperative Station at Norwalk are given in Table B-1, Appendix B.

24. PRECIPITATION

The annual rainfall at Westport is about 46 inches, distributed rather uniformly throughout the year. This is based on a record period of 68 years (1892-1959) at Norwalk. During this period of record the annual precipitation has ranged from a minimum of about 34 inches in 1935 to a maximum of 63 inches in 1955. The average monthly rainfall at Norwalk has varied from 4.84 inches in August to 3.34 inches in June. Extremes in monthly precipitation have ranged from 17.23 inches in October 1955 to 0.07 inches in May 1903. A summary of monthly precipitation data at Norwalk is contained in Table B-2, Appendix B.

HISTORY OF HURRICANES AND OTHER GREAT STORMS

25. HISTORICAL HURRICANES AND GREAT STORMS

Descriptions of hurricanes and other severe storms striking the southern coast of New England can be found in the diaries and records of the first settlers of the Massachusetts Bay Colony. William Bradford, in his chronicle, "Of Plymouth Plantation, 1620-1647," describes a very severe storm that occurred along the coast of Massachusetts on 15 August 1635. Another great hurricane, on 3 August 1638, is described by John Winthrop in his "History of New England from 1630 to 1649." There is no record to indicate the effect of these two storms on the shores of Long

Island Sound. There was very little development of the coastal areas of Connecticut until after 1638. However, it is reasonable to assume, on the basis of present knowledge of the nature of hurricane surges, that these storms caused the inundation of lowlands along the coast of Connecticut.

The history of hurricanes in Connecticut dates back to the storm of 19-20 October 1770, during which two vessels were driven ashore at New London. Early newspapers and diaries contain a number of references to severe hurricanes between 1770 and 1900. The four most notable storms during this period are those of 19 August 1788, 24 September 1815, 4 September 1821, and 24 August 1893. Accounts of tidal flooding along the Connecticut coast in severe storms, other than hurricanes, have been recorded since 1767. Available tide gage records at a number of localities along the coast of Connecticut indicate the height of tidal flooding experienced during the past 23 years.

26. RECENT HURRICANES AND GREAT STORMS

More numerous records are available of hurricanes and other storms that have caused tidal flooding along the Connecticut coast subsequent to 1900, with good records existing for the period since 1 January 1938. Among the more famous storms in the past 23 years, all of which caused tidal flooding at Westport, are the following:

Hurricanes	Other Storms
a. 21 September 1938	a. 25 November 1950
b. 14 September 1944	b. 7 November 1953
c. 31 August 1954 (Carol)	

Further data on the history of hurricanes are contained in Appendix C.

27. HURRICANE FREQUENCY

The distribution of recorded hurricane occurrences along the Connecticut coast, by estimated degree of intensity, is shown in the following table:

TABLE 1

RECORDED HURRICANE OCCURRENCES

Connecticut Coast

Category	YEARS 1770-1800	1801-1900	1901-1960	Total
A. Causing severe tidal flooding	1	5	3	9
B. Damage from wind and rainfall*	2	8	14	24
C. Threat to area; no damage	1	4	26	31
	4	17	43	64

*Usually accompanied by high seas and moderate tidal flooding.

The fact that there is a record of 43 hurricane experiences thus far in the 20th Century (1901-1960), as compared with 21 occurrences in the 131-year period between 1770 and 1900, is believed to be due to a lack of records on storm occurrences prior to 1900 rather than a trend toward increased hurricane activity in recent years.

Records indicate that the Westport area of the Connecticut coast has experienced severe hurricane tidal flooding upon three occasions since 1900 and lesser flooding upon at least six other hurricane experiences. In addition, storm tides have caused flooding on at least 19 occasions since early in 1938. Of the hurricane flood experiences since 1900, reliable information on high water marks at Westport is available only for the hurricanes of 1938 and 1954. Data is available on tidal-flood levels experienced at other locations along the Connecticut coast in the 1944 hurricane and other storms. An elevation-frequency curve (see Plate B-4, Appendix B) has been prepared for

Westport, based on (1) elevations of flooding at Westport in two recent hurricanes; and (2) estimated elevations of tidal flooding in other hurricanes and storms based on available information at other Connecticut locations, particularly Stamford and Bridgeport.

With respect to seasonal variations of hurricane occurrences in southern New England, the period of greatest activity extends from early August to the end of October. However, records indicate occurrences as early as the middle of June and as late as the middle of December.

HURRICANE CHARACTERISTICS

28. GENERAL DESCRIPTION

The term "hurricane" is applied to an intense cyclonic storm originating in tropical or subtropical latitudes in the Atlantic Ocean north of the equator. Accumulation of heat close to the surface of the water provides energy for water vaporization and the movement of masses of moist tropical air. A hurricane is characterized by low barometric pressures, high winds (75 miles per hour or greater), heavy clouds, torrential rain, tremendous waves, and tidal surges.

29. ORIGINS AND TRACKS

Most of the hurricanes that have affected the eastern coast of North America have formed either near the Cape Verde Islands or in the western Caribbean Sea. Cape Verde hurricanes move westerly for a number of days with a forward speed of about 10 mph. Occasionally, they proceed straight to the coast of Texas but, generally, after reaching the middle Atlantic Ocean, they re-curve northerly and then easterly. Frequently they cross the West Indies, sometimes striking the eastern coast of the United States between Key West, Florida, and Cape Cod, Massachusetts. After re-curving, the storms usually increase their forward speed to a rate of 25 to 30 mph and occasionally to a speed of 60 mph. The hurricanes which form in the Caribbean Sea generally move in a northerly direction, across Cuba, then strike either the Gulf or the southeastern shores of the United States. The hurricanes that most severely affect New England usually approach from the south-southwest after re-curving east of Florida and skirting the Middle Atlantic States. The paths

of a number of selected hurricanes are shown on Plate C-1, Appendix C.

30. WINDS AND BAROMETRIC PRESSURE

The highest winds of a hurricane are those within a circular region extending from the edge of the "eye", or calm center, outward for 10 to 15 miles. The diameter of the eye is usually about 15 miles, although the eye of a mature hurricane may frequently be 20 to 30 miles in diameter. Wind movement is not directly toward the low pressure cyclone center or eye of the hurricane but approaches the center in a counter-clockwise spiral. Consequently, the highest wind velocities occur at points to the right of the hurricane's center where the spiral wind movement and the forward motion of the storm are in the same direction. Since destruction by the wind is greatest in the area on the right side of the hurricane, this area is known as the "dangerous semi-circle."

Atmospheric pressure falls rapidly as the center of the hurricane approaches and as the velocity of the wind increases. Minimum barometric readings do not always occur in the center of the eye. In some instances the minimum is reached at the beginning of the calm period, while in others, the minimum is reached at the end of the calm period. Usually the barometric low is about two inches below the normal sea level pressure of 30 inches. However, in several hurricanes, pressures as low as three inches below normal have been recorded. The lowest barometric pressure of record in the United States, 26.35 inches, was recorded at the northern end of Long Key, Florida, on 2 September 1935.

31. RAINFALL

The rainfall at the edge of a hurricane disturbance is light, normally in the form of showers. As the center approaches, the showers increase in frequency and intensity, becoming heavy to excessive near the eye. The heaviest rain usually falls ahead of the eye, driving torrentially from spiral bands of clouds that sometimes produce nearly two inches of rain per hour. In New England, the hurricane of September 1938 caused rainfall of 6 to 8 inches in a one-day period, at a number of locations; in the 1954 hurricane, one-day rainfalls of 4 to 5 inches were recorded. The record rainfall in New England, associated with a hurricane, occurred during Hurricane Diane (August 1955), when a rainfall of 15.7 inches in 24 hours (total storm

rainfall of 19.8 inches in 48 hours) was experienced at Westfield, Massachusetts, 75 miles northeast of Westport. This hurricane, however, had lost its typical characteristics - high winds and surge - by the time it reached and stalled over New England.

32. WAVES

Much of the damage in a hurricane is caused by the waves generated by the hurricane winds. The ultimate size of the waves depends upon the force and duration of the wind and the fetch or distance the wave travels. No data is available on experienced wave heights at Westport during past hurricanes. Computations have been made of the wave heights to be anticipated at Westport in the event of severe hurricanes. See paragraph 40.

33. TIDAL SURGES

Flooding results from the movement of the storm surge, or rise in water level, onto a shoaling coast or into a bay or inlet. The surge is caused by a combination of hurricane winds and low barometric pressure in a storm having a track and speed of forward movement synchronized with the normal pattern of tidal movement and oscillations of the sea in the open ocean.

Generally, the rise of the sea is gradual as the center of the storm approaches but sometimes it comes with great swiftness. The history of terrible storms, revealing many instances of cities and towns flooded, with thousands of lives lost, affords graphic evidence that such rises are not always gradual.

Usually the level of the storm surge is increased by a rising ocean bed and favorable shore contours, factors which similarly affect the astronomical tide in shore locations. The ordinary rise of the tide amounts to only one or two feet in the open ocean while its range is often ten to twelve feet at coastal points. In certain bays and channels the rise is 25 to 50 feet above low water. The times of ebb and flow of such tides are of course well known, but the storm surge comes so rarely to any one community that it is seldom anticipated in its fully developed form. A well defined storm surge is not developed unless the slope of the ocean bed and the contours of the coastline are favorable to its rise, in combination with the proper direction of the storm track and speed of movement. Tidal flooding along the Connecticut coast occurs as

the storm surge accompanying a northward-moving hurricane, following a track east of Westport, moves up Long Island Sound from its eastern end. The time lag for the surge to reach the western end of the Sound is approximately three and one-half hours to reach Westport, approximately two and one-half hours.

DESIGN HURRICANE TIDAL FLOOD

34. WIND FIELD AND BAROMETRIC PRESSURE

In New England, the maximum recorded wind velocity in a past hurricane is a gust of 186 mph at the Blue Hills Observatory, Milton, Massachusetts, in September 1938. The sustained 5-minute velocity at this location, about 135 miles northeast of Westport, during this same hurricane, was 121 mph. At New York City, about 40 miles to the southwest of Westport, the maximum gust and 5-minute velocity in this hurricane were 80 and 70 mph, respectively. At New Haven, Connecticut, 25 miles east of Westport, and at Hartford, Connecticut 55 miles northeast, sustained winds of 38 and 46 mph were recorded with gusts of 46 and 59 mph, respectively, in 1938.

During the hurricane of September 1944, the maximum gust in New England was 109 mph at Hartford, Connecticut. A wind of 99 mph, for one minute, and a 5-minute velocity of 81 mph were recorded at New York City during this storm. At New Haven, Connecticut, the recorded maximum gust was 65 mph and the sustained 5-minute wind was 33 mph.

Peak gusts measured during Hurricane Carol, 31 August 1954, are 142 mph at Mount Washington, New Hampshire, 240 miles northeast of Westport, and 135 mph at Block Island, Rhode Island, 90 miles to the east. Gusts of 65 and 64 mph, respectively, were experienced at New Haven and Hartford.

Low atmospheric pressures are characteristic of the "eye" of a hurricane. The lowest barometric pressure ever recorded in New England is 28.04 inches at Hartford, Connecticut, during the 1938 hurricane. At New Haven, a low of 28.11 inches was recorded during this same hurricane. The New England low for the September 1944 hurricane is 28.31 inches at Point Judith, Rhode Island, located about 90 miles east of Westport. In Hurricane Carol (1954) the pressure fell to 28.20 inches at Storrs, Connecticut, 70 miles northeast

of Westport. A low of 28.77 inches was recorded at New Haven. No records of barometric pressures have been obtained at Westport.

Further data on wind velocities and barometric pressures in past hurricanes are included in Appendix B.

35. ASTRONOMICAL TIDE AND TIDAL FLOODING

An important factor in determining the height of flooding from a hurricane surge is the stage of the normal tide at the time the hurricane surge arrives at the coast. The surge in the September 1938 hurricane added 7.5 feet to the astronomical tide at the mouth of the Saugatuck River and caused flooding to an elevation of 10.5 feet msl (approximately 6.7 feet, mhw). The hurricane of 31 August 1954 (Carol) with a 5.6-foot surge, caused flooding to an elevation of 10.0 feet, msl. Hurricane high-water elevations, predicted coincident astronomical tides, and the storm surges in the three major hurricanes that have struck the town of Westport in recent times are tabulated in Table 2 below.

TABLE 2

TIDAL-FLOOD DATA

Westport, Connecticut

Date	Time of Peak (EST)	Hurricane High-Water Elevation (feet msl)	Coincident Gravitational Tide (feet msl)	Storm Surge (feet)
21 Sep 1938	7:38 PM	10.5	3.0	7.5
14 Sep 1944	11:24 PM	9.1	2.2	6.9
31 Aug 1954	12:42 PM	10.0	4.4	5.6

The duration of tidal flooding, above the elevation of mean high water, was about 4.5 hours in the 1938 hurricane and about 5.5 hours in the 1944 and 1954 hurricanes. Further data on tidal high water elevations may be found in Appendix B.

Peak flooding at Westport in the 1938 hurricane occurred about one hour and forty-five minutes before a predicted astronomical high tide of 4.8 feet msl; in the 1944 hurricane, approximately two hours after a predicted high tide of 4.0 feet msl. Peak flooding in the 1954 hurricane occurred practically coincident with the peak of a predicted high tide of 4.4 feet msl. The greatest surge was 7.5 feet, experienced in the 1938 storm. Although the surge in the 1954 hurricane was nearly two feet less than that of 1938, the elevation of tidal flooding in 1954 was only one-half foot below the 1938 level due to the higher stage of coincident tide at the time of peak flooding. Similarly, although the 1944 surge exceeded the 1954 surge by 1.3 feet, the elevation of flooding in 1944 was 0.9-foot below the level experienced in 1954. Had the surge in 1954 been equal to the 1938 surge, flooding in 1954 would have reached an elevation of 11.9 feet msl, or 1.9 feet above the level which was actually experienced in 1954. If these three hurricanes had struct Westport at a time coincident with a high spring tide of 5.6 feet msl, flooding would have been experienced to an elevation of 13.1 feet msl in 1938; 12.5 feet msl in 1944, and 11.2 feet msl in 1954m or, respectively, 2.6, 2.0, and 0.7 feet above tidal-flood level experienced in 1938.

In determining future tidal-flood levels, one factor to be considered is the rise in mean sea level that is taking place along the New England coast. Continuing investigations being made by the U.S. Coast and Geodetic Survey in regard to changes in sea level indicate that the elevation of mean sea level has risen at a rate of approximately 0.02 foot per year since 1930. (See report by the Council on Wave Research in Proceedings of the First and Second Conferences on Coastal Engineering, 1952). If this trend continues and storms of the magnitude of the 1938 and 1954 hurricanes were to occur at the end of the next 50 years, the flood levels at that time would be approximately one foot higher than the levels that were actually experienced in these storms. The effect of rising sea level is to increase the severity of future hurricane tidal flooding.

36. STORM TRACKS

Each of the three recent great hurricanes, namely those of 1938, 1944, and 1954, followed paths located to the east of Westport; the 1938 hurricane path being about 15 miles to the east, the 1954 hurricane, 65 miles; and the 1944 hurricane, 75 miles. These paths were not critical to Westport insofar as wind intensities were concerned but they did place the eastern entrance of Long Island Sound in a

sector of each hurricane where high storm surges are experienced. These surges then traveled up the Sound to produce tidal flooding at Westport. A hurricane surge entering New York Harbor, by reason of a storm following a path west of Westport, would undergo a considerable reduction in magnitude before entering the western end of Long Island Sound by way of the East River.

37. STANDARD PROJECT HURRICANE

A project hurricane for use in the design of protective structures has been established through the cooperation of the U. S. Weather Bureau and the Beach Erosion Board, assisted by personnel of the Agricultural and Mechanical College of Texas. The basis for the project storm is a transposition of the September 1944 hurricane. This hurricane, off Cape Hatteras, had the greatest amount of energy of any known hurricane, including that of September 1938. I. R. Tannehill, in his book, "Hurricanes: Their Nature and History," states in reference to the September 1944 hurricane, ". . . . . there is no definite proof of a more violent hurricane in the records." However, the 1944 hurricane when it struck New England was not nearly so serious along the Connecticut coast as either the September 1938 or the August 1954 hurricanes because its energy had been partly dissipated over the land during its northward travel from Cape Hatteras. Moreover, it struck at a time of lower tide.

In deriving the project hurricane, the 1944 storm was transposed so that it would be entirely over water from the Cape Hatteras area to the New England coast. This change in the track of the storm results in less rise in barometric pressure at the center of the storm as it moves northward than was actually experienced in 1944. The transposed hurricane is assumed to advance in a due northerly direction with a forward speed of 40 knots (about 46 mph) in one case, 30 knots (about 34 mph) in a second case, and to pass over New England at a point 49 nautical miles (56 statute miles) west of Montauk Point, Long Island, near the eastern entrance to Long Island Sound This change in the track of the storm produces the highest surges along the Connecticut coastline, on the north shore of Long Island Sound.

38. STANDARD PROJECT HURRICANE SURGE

The surge at the eastern entrance to Long Island Sound, in the September 1938 hurricane, has been calculated at 9.5 feet. The surge at this same location, in the event of a project hurricane, has

been determined to equal 13.4 feet or 1.4 times the 1938 surge. Routing this 13.4-foot surge up Long Island Sound gives a project hurricane surge of 9.2 feet at the mouth of the Saugatuck River at Westport. The computation of these storm-tide potentials has been made by members of the staff of the Department of Oceanography of the A. & M. College of Texas in connection with research work conducted by them for the Beach Erosion Board. Further information on the derivation of the project surge is contained in Appendix B.

39. DESIGN FLOOD LEVEL

The addition of a Standard Project Hurricane surge of 9.2 feet on top of a mean spring tide at 4.4 feet msl would result in flooding to an elevation of 13.6 feet msl or 3.1 feet higher than the level of flooding experienced in 1938. As indicated later in this report, see paragraph 59, protection based on flooding to this elevation of 13.6 feet msl is not economically justified when compared with protection of a lesser degree. Moreover, local interests have voiced objections to high dikes and walls. They have expressed a desire for protection, but only to the record height of flooding experienced in 1938. This gives a design flood level of 10.5 feet msl which is equivalent to a project hurricane surge of 9.2 feet coincident with a tide at 1.3 feet msl. A tide at 1.3 feet msl would be 4.5 feet above mean low water and would equal approximately two-thirds of an average tide.

40. DESIGN WAVES

Computations based on a fetch of 10.6 nautical miles and a wind velocity of 55 mph, from the west southwest, at the time of a peak surge in a project hurricane at Westport, indicate that a six-foot significant wave would be experienced off the shore where the water depth is sufficient to support this size of wave. With flooding to the design level of 10.5 feet msl, as experienced in 1938, the maximum wave that would break upon a structure along Soundview Drive at Compo Beach, owing to depth limitations, would be one with a height of approximately 2.0 feet.

Insofar as potential wave heights at Westport are concerned, project hurricane conditions are not the most severe. The most critical condition would occur with a hurricane centered west of Westport, near New York City. Under such a condition, a wind

of 95 mph, from the south, could be experienced which would create a 13-to 14-foot significant wave offshore. Under such a condition, however, there would be little or no storm surge at Westport. The size of wave that would break on the protection would be dependent upon the depth of water at the toe of the structure.

Significant wave heights are equivalent to the average height of the highest one-third of all the waves in a wave train. These heights are exceeded by about 13 percent of all the waves in the train, the maximum wave heights being about 60 percent higher and occurring about one percent of the time.

41. STORM RAINFALL

The computations of the runoff from the drainage area behind the considered dike protection for the Compo Beach area of Westport, made for the purpose of determining the residual losses from ponding, were based on the actual rainfalls that occurred during the hurricanes of 1938, 1944, and 1954, and the storm of October 1955; also on an assumed 10-year, 6-hour, rainfall coincident with a design tidal-flood level of 10.5 feet msl.

The maximum 6-hour rainfalls in the recently experienced hurricanes at Westport, which it is assumed would have contributed to ponding behind dike protection in the Compo Beach area, were 1.80 inches in 1938, 3.90 inches in 1944, and 1.13 inches in 1954. The maximum 6-hour rainfall of 6.92 inches in the October 1955 storm is the record at Westport. This rainfall has a frequency of well in excess of 100 years.

42. STORM RUNOFF

Approximately one-half of the contributing drainage area of 42 acres is a steep-sided, grass and brush covered hill, on the north side of Compo Road South, which has been partially developed for residential purposes. The remaining area of 51 acres, on the south side of Compo Road South, is quite flat and is extensively utilized by private residences and grounds. Hydrographs of the runoff, for the five rainfall conditions mentioned above, in paragraph 41, were derived by the synthetic unit graph method. An infiltration rate of 0.25 inches an hour and a concentration time of one-half hour were assumed as being applicable to the area. The estimated runoffs from the 93-acre drainage area behind the considered Compo Beach

dike protection are tabulated below:

Storm	Rainfall (6-hour) (inches)	Runoff (6-hour) (ac. ft.)	Runoff (6-hour) (inches)
Hurricane, 1938	1.80	4.3	0.55
Hurricane, 1944	3.90	19.8	2.56
Hurricane, 1954	1.13	1.9	0.25
Storm, Oct 1955	6.92	42.0	5.42
10-Year	3.45	19.0	2.45

EXTENT AND CHARACTER OF FLOODED AREA

43. The hurricanes of 21 September 1938 and 31 August 1954 caused tidal flooding to elevations of 10.5 and 10.0 feet msl, respectively, at Westport. At these elevations over 1,150 acres were inundated in the town, as outlined on Plate 1. Three residential areas along the shore, overlooking Long Island Sound - the Greens Farms, Compo Beach, and Saugatuck Shores areas - and both banks of the Saugatuck River, along the lower 4.5 miles, are subject to tidal flooding. Nearly 60 percent of the damage experienced in 1954 occurred along the shore between the mouth of Sasco Brook, at the Fairfield-Westport town line, and Hendricks Point on the east bank of the Saugatuck River about one mile above its mouth.

In the Greens Farms area, the seawalls and grounds of eight large private estates near Frost Point are exposed to erosion damage and about 20 cottages in the Sherwood Pond area, west of Sherwood Island State Park, are subject to the flooding of grounds and cellars. The Compo Beach-Owenoke Park residential area includes about 220 dwellings, primarily year-round, a group of municipal bathhouses and a town-owned yacht club, which are vulnerable to flooding. In the flooded Saugatuck Shores area, on the west bank at the mouth of the Saugatuck River, are approximately 90 summer and year-round homes. Immediately upstream of the Saugatuck Shores area, along one mile of the river, are 17 large homes and private estates that sustain damage to grounds and seawalls from tidal flooding during severe storms. Above this residential section, in the flooded area along the west bank of the river, for two miles to the head of tidewater, there are

about 23 dwellings, approximately 18 commercial establishments, three industrial firms, and a fire station. In the main business center of the town, along 0.3 mile of the east bank of the river, about four miles above the mouth, are 42 commercial establishments, 18 dwellings, a library, and a YMCA, which are subject to inundation.

HURRICANE TIDAL-FLOOD DAMAGES

44. FLOOD-DAMAGE SURVEY

Information on tidal-flood damages sustained as a result of Hurricane Carol, 31 August 1954, was obtained by damage surveys conducted immediately after the hurricane and in 1956. Data were collected on the extent and nature of the areas flooded, the depth of flooding, and the amount of damage experienced during this hurricane. Estimates were made of the recurring loss potential at the 1954 flood level and at various stages above and below the 1954 level to develop stage-loss relationships. Much of the information was obtained through personal interviews and inspections, with sampling methods being used whenever similar types of property, subject to approximately the same depth of flooding, were encountered. Field and office reviews were made in 1960 to note physical changes in the flood area since the 1956 damage survey and to review damages in the Compo Beach residential area.

45. EXPERIENCED TIDAL-FLOOD DAMAGES

Hurricane Carol in 1954 caused damages from tidal-flooding in Westport, along the shores of Long Island Sound and the Saugatuck River, that are estimated at $940,000. Nearly 80% of the total loss was experienced by residential properties, with damage to commercial properties accounting for a major portion of the remaining loss. Approximately 60 homes, 50 commercial establishments, and a fire station experienced up to three feet of flooding on their first floors. Major portions of the total residential damage occurred in the Compo Beach and Saugatuck Shores areas. Over 60 percent of the commercial damage was experienced in the main business district on the east bank of the Saugatuck River, north and south of State Street, U. S. Route 1. Most of the remaining commercial loss was experienced along the west bank

of the river in the tidewater area upstream of the New Haven Railroad bridge. The distribution of the total flood loss, by type of damage, is shown in Table 3.

TABLE 3

EXPERIENCED TIDAL-FLOOD DAMAGES

HURRICANE CAROL, 31 AUGUST 1954

Westport, Connecticut

Type of Loss	Damages
Residential	$740,000
Commercial	140,000
Public	40,000
Industrial	10,000
Highway	10,000
Total	$940,000

46. RECURRING TIDAL-FLOOD DAMAGES

Estimates have been made of the recurring damages that would be experienced in the future from tidal-flooding at various stages above and below the 1954 flood level. In the event of a future tidal flood of 1954 magnitude, at an elevation of 10.0 feet, msl, a loss of $1,070,000, at 1960 price levels, would be experienced in Westport. A summary of the losses to be anticipated in a recurring 1954 hurricane, by type of damage is presented in Table 4.

TABLE 4

RECURRING 1954 TIDAL-FLOOD DAMAGES
(1960 Price Level)

Westport, Connecticut

Type of Loss	Damages
Residential	$840,000
Commercial	180,000
Public	30,000
Industrial	10,000
Highway	10,000
Total	$1,070,000

A recurrence of the 1938 hurricane, with flooding to an elevation of 10.5 feet, msl, would cause estimated damages in an amount of $1,400,000; a recurrence of the 1944 flood stage of 9.1 feet msl, damages of $540,000. Additional data on recurring losses in Westport are included in Appendix D.

47. AVERAGE ANNUAL TIDAL-FLOOD LOSSES

Average annual tidal-flood losses in Westport, for flood stages at and below an elevation of 13.6 feet, msl, are estimated at $187,000. This elevation of 13.6 feet represents a Standard Project Hurricane surge of 9.2 feet on top of a mean spring tide at 4.4 feet, msl. The estimate of annual loss has been determined from a correlation of stage-loss with stage-frequency data to obtain a curve of damage vs. frequency. The stage-frequency data reflects observed tidal-flood elevations in Westport for the September 1938 and August 1954 hurricanes supplemented by stage-frequency information pertaining to Stamford and Bridgeport, Connecticut. The area under the damage-frequency curve represents average annual losses.

EXISTING CORPS OF ENGINEERS PROJECTS

48. HURRICANE PROTECTION

There is no existing Corps of Engineers hurricane protection project for the prevention of tidal-flood damages in the town of Westport.

49. NAVIGATION

Federal improvement of Westport Harbor and the Saugatuck River in the interest of navigation dates back to 1827. The existing navigation project provides for the following:

a. A channel 9 feet deep, 125 feet wide across the outer bar, and generally 100 feet wide to the highway bridge at Saugatuck, thence 4 feet deep, 60 feet wide up to Westport.

b. A turning and anchorage basin 6 feet deep, about 3.5 acres in area, downstream of the highway bridge at Saugatuck.

c. A riprap breakwater about 540 feet long at Cedar Point.

d. Removing ledge opposite Stony Point and boulders from the channel.

The existing project is 25 percent completed. To complete the project there remains the dredging of the 9-foot channel and 6-foot turning basin and anchorage and removal of ledge from the channel at Westport. The mean low water controlling depths in the channel, in 1956, were: 7.0 feet across the outer bar, thence 3.0 feet to Saugatuck and to the lower wharves at Westport, thence one foot and less to the upper wharves. In the turning basin and anchorage area the controlling depth was zero to one foot, at mean low water, in 1956.

50. BEACH EROSION CONTROL

The existing project provides for Federal participation in the amount of one-third of the first cost of construction of the following plans of protection and improvement.

a. Burial Hill Beach. Widening to 100 feet about 500 feet of beach by the direct placement of sand. This is contingent upon the construction, under the plan for Sherwood Island State Park, see below, of a 400-foot training wall on the east bank of Burial Hill Creek.

b. Sherwood Island State Park. Widening to 150 feet about 6,000 feet of beach by direct placement of sand; the creation of a stockpile by direct placement of sand for an additional width of 100 feet for a distance of 1,000 feet east and 1,000 feet west of Sherwood Point; the construction of two training walls 400 and 500 feet long at Burial Hill Creek; and the construction of an impermeable groin 500 feet long at the west end of the improvement.

c. Compo Beach. Widening to 100 feet the beaches east and west of Cedar Point, about 2,600 and 1,000 feet long, respectively, by direct placement of sand; and the construction of two impermeable groins, each 500 feet long, one at Hills Point and one at the west end of the improvement.

Construction of the above improvements was completed during the years 1956 to 1958.

HURRICANE PROTECTION IMPROVEMENT BY OTHERS

51. No improvements in the interests of minimizing hurricane tidal-flood damages in Westport have been undertaken by any other Federal agencies, by the State of Connecticut, or by the Town.

IMPROVEMENTS DESIRED

52. MEETINGS WITH LOCAL INTERESTS

During the course of the survey a number of meetings have been held with representatives of both State and local governments as well as with representatives of residents in the Compo Beach area of the town. The purposes of the meetings have been to ascertain the desires of local interests, to acquaint them with the progress being made on the survey, and to afford an opportunity for the exchange of ideas and comments on the survey and the various plans of protection being considered. At these meetings, local interests stressed the

need for some tidal-flood protection, especially for the residential areas along the shore. They modified their desire, however, by requesting that the degree of protection be based on the flood level of record experienced in 1938.

53. PUBLIC HEARING

A public hearing was held in Westport, Connecticut, on 31 March 1960, for the purpose of acquainting local interests with the results of the survey and determining their views and opinions. The meeting was attended by about 75 persons, including State and local officials, representatives of local industrial and commercial interests, and a number of home owners.

Considered plans of protection for the Compo Beach area of the town and the business district on the east bank of the Saugatuck River, north and south of State Street (U. S. Route 1), were described by representatives of the Corps of Engineers. A number of local residents in the Compo Beach area voiced a need for protection and expressed their general approval of a considered plan that afforded limited protection against the record flood stage of 1938. Several stressed the point that their main difficulty stemmed from flooding from Grays Creek rather than flooding from Long Island Sound, over Compo Beach Road and Soundview Drive. Some were of the opinion that protection against flooding from Grays Creek would alone be sufficient to meet their needs. There were some expressed objections to the height of considered dike protection along Soundview Drive owing to the loss of view, loss of beach, and general appearance. No expressions of opinion were forthcoming in regard to protection of the main business district of the town. Several representatives of industrial and commercial interests on the west bank of the Saugatuck River, near the head of navigation at State Street, where protection was found to be not justified, indicated a desire for protection of their properties.

TIDAL FLOOD PROBLEM AND SOLUTIONS CONSIDERED

54. TIDAL-FLOOD DAMAGES

Hurricane damages result chiefly from (1) salt-water flooding caused by the hurricane surge, (2) action of storm-driven waves, (3) fresh-water flooding resulting from hurricane rains, and (4) the

effect of high velocity winds. This report is concerned mainly with the damages arising from salt-water tidal flooding and to a lesser degree with the damages caused by wave action. Damages caused by hurricane winds are not included in the study. The inundation of low coastal areas by hurricane tides and the fresh-water flooding in river valleys account for the major portion of hurricane damages. Hurricane Carol (August 1954)caused severe flooding of shorefront areas along the Connecticut coast, including Westport. In the following year, the rainfall associated with Hurricane Diane inflicted heavy flood damages along the river valleys in Connecticut, Massachusetts, and Rhode Island. However, by the time this storm reached New England it had slowed down considerably and lost the general characteristics of a hurricane.

Damages are also incurred along the Connecticut shore by severe storms, other than hurricanes, that are accompanied by strong easterly winds. Since the Connecticut shore is practically landlocked, these storms can cause abnormally high tides. Storms of this nature in November 1950, November 1953, and other occasions, as recent as February 1960, have caused serious tidal-flooding in areas of Westport.

Damages caused by hurricanes and other great storms take many forms, including loss of life and property, hazards to health, disruption of normal economic activities, and costs of evacuation and reoccupation. Some types of damages cannot be prevented, although they may be relieved by careful planning. Damages resulting from tidal-flooding of coastal areas can be significantly reduced in some cases by protective structures.

55. HURRICANE FLOOD PROBLEM

The problem, in general, resolves itself into one of determining the possibilities of obtaining protection for as great a portion of the flooded areas of Westport as can be economically justified by the resulting benefits. These areas, mainly urban in nature, sustained damage of $940,000 from tidal-flooding in Hurricane Carol on 31 August 1954. The greater part of this damage, approximately 75% of the total, was experienced in residential areas directly exposed to hurricane tidal-surges from Long Island Sound.

56. DEGREES OF PROTECTION CONSIDERED AND DESIRED

The minimum degree of considered protection is predicated on the fact that Westport experienced tidal flooding to an elevation approximately 6.7 feet above mean high water (10.5 feet msl) in the hurricane of 21 September 1938 and to an elevation about 6.2 feet above mean high water, (10.0 feet msl) in Hurricane Carol on 31 August 1954. Properties in the flooded area along the shore were inundated to depths ranging up to three feet on their first floors. Protection against flooding to the level experienced in 1938 is the maximum desired by local interests. The maximum degree of considered protection in the study of the Westport tidal-flood problem was based on a project hurricane surge of 9.2 feet arriving at Westport coincident with the peak of a mean spring tide and causing flooding to an elevation of 9.8 feet above mean high water (13.6 feet msl). In arriving at the top elevation of protective works for a selected flood level, an increase in height above the level of flooding has been provided in order to minimize the effects of overtopping by waves.

57. PROTECTIVE MEASURES CONSIDERED

Protective measures fall into the following categories: (a) hurricane warning and emergency flood mobilization measures, including plans for evacuations; (b) revised zoning regulations and building codes; and (c) protective structures such as dikes, walls, and barriers designed to afford protection for areas along the shore subject to tidal flooding. These measures are described below:

a. Hurricane warning and emergency flood mobilization measures. A hurricane warning system, combined with emergency mobilization and plans for evacuation, would materially aid in preventing loss of life and property. Such a system, however, would not alleviate the problem of physical inundation of properties. Considerable time is required for emergency precautionary measures, such as boarding up and sandbagging windows, evacuating low-lying areas, removing goods and equipment to higher levels, pulling small craft ashore, and driving vehicles to high ground. A warning system, no matter how expensive and elaborate, may not always provide sufficient time for taking adequate precautions. The hurricane of 1938, for example, which was reported stalled at one time off Cape Hatteras, swept north to the New England coast, almost unannounced, only eight hours later.

Hurricane alerts and "near misses," resulting only in "scares," interfere with the normal activities of the affected residents and, in many cases, cause economic loss. The hurricane warning services now provided by the U. S. Weather Bureau are necessary, however, to supplement any plan of protection for Westport.

b. Revision of zoning regulations and building codes. The consideration of warnings and emergency measures leads to thought being given to the relocation of goods and equipment to higher floor levels, relocation out of the flood area entirely, or of more substantial construction to resist the destructive forces of high water and waves. State and local governments, in some instances, have proposed adoption of zoning restrictions to prevent new construction in critical flood areas and revisions of building codes to require sturdier construction in areas where buildings have been demolished by storm tides. Such measures, where proposed for existing concentrations of homes, commercial establishments, and industries, tend to meet with strong opposition because of the high investment in property and the prospective loss to property owners and municipalities. The responsibility for enacting legislation on zoning and building regulations lies with the State and municipalities concerned.

c. Protective Structures. Although hurricane warnings, mobilization measures, and revised zoning regulations and building codes will abate the extent of flood damages, they will not eliminate the inherent danger from tidal flooding. The most positive means of protection consists of structures which will physically reduce or prevent the inundation of properties by tidal-flood waters at the time of a hurricane or other great storm. Considered structures include barriers, with gated or ungated openings, which would completely or partially close off the waterway to the entry of hurricane tides; dikes or walls along the shore, which will hold back the high water; or a combination of barriers, dikes, and walls. The construction of breakwaters, or the enlargement of existing breakwaters, would effect a reduction in the height of hurricane waves but would be ineffective in preventing the flooding of shore properties.

58. PLANS CONSIDERED

Studies have been made of a number of plans for reducing hurricane tidal-flood damages in Westport. In general, the plans may be considered to fall into one of two categories: barriers or local protection.

a. Barriers. Two considered plans provided for rock-faced barriers across the Saugatuck River to afford protection to upstream properties. One was located at the narrowest point in the river, near River Court, about 3,000 feet upstream from the Connecticut Turnpike bridge at Saugatuck and 4,000 feet downstream from State Street. This plan included a gated conduit through the barrier to pass the river flow under normal conditions and a pumping station to handle the flow when river stages downstream are high. The second plan called for a barrier across the mouth of the river, from Cedar Point to Saugatuck Shores, with dike closures to high ground west of Saugatuck Shores and in the Compo Beach area of the town. In the study of barrier protection at this second location, consideration was given to an ungated opening for navigation through the barrier and also to the provision of a 75-foot wide gated opening that would be closed during times of hurricane and other storm surges.

b. Local Protection. The possibilities of local protection by dikes, walls, and sandfill were investigated for several areas of concentrated damages. The locations and nature of considered protection are listed below:

(1) Greens Farms. Placement of sandfill forward of the existing seawalls, along approximately one mile of shore in the eastern part of the town, to reduce the wave attack and resulting damage to existing seawalls.

(2) Compo Beach. Construction of dike to afford protection for residential properties in the Compo Beach - Gray's Creek area. See paragraph 60.

(3) Business District (East Bank). Raising of existing walls and construction of dike and wall closures to high ground to afford protection for the business district on the east bank of the Saugatuck River, north and south of State Street.

(4) Business District (West Bank). Construction of dikes and walls along the west bank of the Saugatuck River to afford protection for industrial and commercial properties above and below State Street.

(5) Saugatuck Shores. Construction of dike and sandfill protection along the two-mile perimeter of this low-lying area in one southwestern part of the town.

59. SELECTION OF PLAN OF PROTECTION

a. Barriers. The plans for barriers across the Saugatuck River were eliminated from detailed consideration early in the survey since preliminary estimates of benefits and costs revealed the projects to be economically unfavorable. Annual costs amounted to three or more times the annual benefits. The plan incorporating an ungated navigation opening through a barrier at the mouth of the river was found to afford only minor reductions in flood levels upstream owing to insufficient storage capacity behind the barrier.

b. Greens Farms. Preliminary study of the plan for placement of sandfill forward of the seawalls at Greens Farms indicates that such a program would have a benefit-cost ratio of approximately one. However, since practically all of the benefits would result from the prevention of damage to privately owned walls, the improvement is considered to be more in the nature of a beach erosion prevention measure and not one to be accomplished under hurricane protection. Local officials have informally concurred in this opinion, ~~and have informally concurred in this opinion~~, and have indicated that Town support for such a plan would be lacking.

c. Business District (East Bank). Protection of this area against a recurring 1938 flood stage of 10.5 feet msl falls short of attaining economic justification. The annual costs exceed the annual benefits by a small amount. Increasing the degree of protection to a flood stage of 12.5 feet msl, two feet above the 1938 level, results in a justifiable project with annual benefits exceeding costs by approximately 25 percent. As the degree of protection is increased above 12.5 feet msl, the ratio of annual benefits to costs decreases. For protection based on flooding to 13.6 feet msl, the annual benefits exceed the costs by only about 10 percent. Protection of this area has been dropped from further consideration since (1) local interests do not desire protection for flood stages in excess of the record level of 10.5 feet msl experienced in 1938, (2) protection against flooding to an elevation of 10.5 feet msl lacks economic justification, and (3) there is no strong local desire for even a limited degree of protection in this area.

d. Business District (West Bank). A study of preliminary nature indicates that the protection of this area against any degree of flooding, between the record 1938 level of 10.5 feet msl and a stage four to five feet higher, is not economically justified.

e. Saugatuck Shores. Preliminary studies indicate that the cost of protection would be high in comparison to the benefits, equaling approximately four times the benefits on an annual basis.

f. Compo Beach. Dike protection for this area of Westport to an elevation of 10.5 feet msl as experienced in 1938, is economically justified and is the selected plan of protection for Westport. See paragraph 60. Increasing the degree of protection, by raising the height of the dike, results in decreasing the ratio of annual benefits to annual costs. This latter ratio, although decreasing as the height of the dike increases, remains favorable for projects based on flooding up to and above 13.6 feet msl. The additional annual cost incurred by providing protection against a flood level of 13.6 feet msl as compared with a flood level of 10.5 feet msl is approximately 60 percent greater than the additional annual benefits that would be obtained.

HURRICANE TIDAL-FLOOD CONTROL PLAN

60. GENERAL DESCRIPTION

The selected hurricane protection plan for Westport, shown on Plate 2 of this report, consists of dike protection for the residential area in the vicinity of Compo Beach that is bounded by Compo Road South, Compo Beach Road, and Soundview Drive. The protection starts at high ground on the southwest side of Compo Hill, on the east bank of Grays Creek, about 300 feet north of Compo Road South. The alignment runs southerly about 2,250 feet, along the east shore of the creek, on the west side of Compo Beach Road, to Agawam Avenue; continues easterly, 1,460 feet, along the south side of Compo Beach Road to Soundview Drive; then along the seaward side of Soundview Drive, for about 1,510 feet, to its intersection with Compo Road South and Hills Point Road. The dikes would be constructed of earth fill and, with two exceptions, have rock on their top and seaward slope and seeded topsoil on the landward slope. One exception is the dike along Soundview Drive where both faces would be of rock. The second exception consists of two short lengths of dike, one, 300 feet long, at the westerly end of the protection, north of Compo Road South, and one, 130 feet long, immediately west of Compo Beach Road at Agawam Avenue, which would have seeded topsoil on both the landward and seaward slopes.

The top elevation of the dikes would vary with the location and be dependent on the size of wave that could break upon the dike. From Compo Hill to Agawam Avenue the dike would have a top elevation of 11.0 feet msl; along Compo Beach Road, from Agawam Avenue to Soundview Drive, the top would be at 11.5 feet msl; and along Soundview Drive the top would be at 13.5 feet msl. Where the protection crosses existing highways, ramps are proposed to bring the roadway elevation up to the desired protection grade. One ramp is just west of the intersection of Compo Road South and Compo Beach Road; one at the intersection of Compo Beach Road and Agawam Avenue; one at the intersection of Compo Beach Road and Soundview Drive, at Soundview Plaza; and one at the intersection of Soundview Drive, Compo Road South, and Hills Point Road.

61. SEWER AND DRAINAGE MODIFICATIONS

No modifications to existing sewerage facilities would be necessitated by the construction of the proposed protection. All existing drainage lines which pass under the proposed dikes would be strengthened or replaced in order to carry the added weight to which they will be subjected. Several new drainage lines would be installed under the dikes to maintain present drainage conditions. Some minor grading and additional catch basins would be required. All existing and proposed drainage lines would be provided with flap gates on the seaward side of the dikes and with emergency mechanically-operated sluice gates on the landward side to prevent the entry of tidal waters.

62. RELOCATION OF UTILITIES

It would be necessary to relocate several utility poles and one telephone booth which are now within the construction area.

63. LANDS AND RIGHTS-OF-WAY

Construction of the project would require the acquisition in fee or the securing of permanent easements on approximately six acres of land, and temporary easements on an additional three and one-half acres for the period of construction. Approximately 60 percent of the land to be covered by both permanent and temporary easements is park or beach property presently owned by the Town of Westport. No privately owned homes or improvement would have to be acquired.

64. HYDROLOGIC AND HYDRAULIC CONSIDERATIONS

The proposed protection for the Compo Beach area was designed on the basis of the following criteria:

a. A design stillwater level of 10.5 feet msl experienced by reason of a project hurricane surge of 9.2 feet arriving at Westport coincident with a tide at 1.3 feet msl. The design level of 10.5 feet msl equals the flood stage that was experienced in September 1938.

b. Ponding behind the protection based on:

(1) Runup and overtopping of the protection by significant storm waves ranging up to two feet in height at the dikes.

(2) Experienced rainfalls in the 1938, 1944, and 1954 hurricanes and the October 1955 storm, and a 10-year frequency rainfall of 3.45 inches in six hours as determined from U.S. Weather Bureau Technical Paper No. 29, Rainfall Intensity - Frequency Regime.

(3) Runoff predicated on an assumed infiltration rate of 0.25 inch per hour.

Further data on the hydrologic and hydraulic factors that have been considered in the design of protective works are contained in Appendix B.

65. DEGREE OF PROTECTION AND PONDING

The proposed dike plan would afford complete protection against future tidal-flooding up to an elevation of 10.5 feet msl for approximately 65 acres in the Compo Beach area of Westport. Although the protected area represents only about five percent of the entire flooded area in the town in 1938, it is an area in which over 25 percent of the total tidal-flood damages were experienced at that time. Tidal flooding to an elevation of 10.5 feet msl is estimated to have a two percent or one in fifty chance of occurrence each year. It is reasonable to anticipate that the protection would be overtopped at least once during an estimated 50-year life by the occurrence of a hurricane causing tidal flooding to an elevation above 10.5 feet msl.

Although the dikes and appurtenant works would prevent the inundation of the protected area from tidal-flooding at or below an elevation of 10.5 feet msl, some residual damages would be experienced in

the protected area by reason of the ponding of runoff from rainfall behind the dikes. Data on estimated runoff from the contributing drainage area of 93 acres is contained in paragraph 42. A recurrence of the rainfall and other conditions experienced during the 1954 hurricane would result in practically no interior ponding. Ponding upon the recurrence of 1938 hurricane conditions would reach an elevation of approximately 4.8 feet msl, or 5.7 feet below the 10.5-foot flood stage that would be experienced with no protection. This pond level of 4.8 feet msl is 0.2 foot below the stage of 5.0 feet msl where damage from ponding begins. With the recurrence of the conditions experienced in the 1944 hurricane and the storm of October 1955, and in the event of a 10-year, 6-hour rainfall occurring concurrent with a tidal-flood level of 10.5 feet msl, the interior runoff would pond to elevations of 6.6, 7.4, and 6.4 feet msl, respectively. At these stages of ponding, which would be of rather infrequent occurrence, damages would range from about $9,000 to $25,000. On an annual basis this ponding is estimated to represent a loss of $2,000.

66. EFFECT OF PLAN ON OTHER INTERESTS

The hurricane protection plan for Westport would have no effect on existing navigation facilities, the fishing and wildlife resources of the area, or present sanitary conditions. Further, the plan would have no adverse effect on the present recreational facilities and activities in the area. It is proposed through the placement of sandfill to replace the area of beach occuped by the dike so that the area available for recreational use would be approximately the same after construction of the project as before construction.

67. EFFECT OF PLAN ON ADJACENT SHORELINE

The plan of dike protection for the Compo Beach area of Westport would not cause accretion or erosion along the adjacent shoreline.

ESTIMATES OF FIRST AND ANNUAL COSTS

68. The estimated total first cost of the project, based on 1960 prices, is $310,000. This includes allowances for engineering and design, and for supervision and inspection during construction. Adding the cost of preauthorization studies gives a total project cost of $320,000. Total annual charges (financial cost) amount to

$15,300. This includes interest at a rate of 2.625 percent on the Federal investment and 3.5 percent on the investment by local interests, amortization over a 50-year project life, and an allowance of $3,000 for annual operation and maintenance. This latter figure includes a charge to cover the cost of major repairs that would be necessary in the future if the dikes were overtopped by tidal-flooding above the design stage of 10.5 feet msl.

For the economic analysis of the project an adjusted annual cost of $16,200 (economic cost) was used as given in Table 5. The "economic costs" of a project, from the broad public viewpoint, are the values foregone, in alternative uses, of the goods and services required in project construction, maintenance, and operation. The "economic costs" for the hurricane protection plan for the Compo Beach area at Westport differ from the "financial costs" in the respect that the interest charges are increased by $900 to allow for the net loss of productivity of the land required for project use. This is based on the difference between the normal return on land, which is about 5.5 percent of its market value, and the local interest rate of 3.5 percent used for calculation of the financial costs.

A summary of the first and annual costs is given in Table 5 on the following page. The figures in the tabulation are based on local interests bearing 30 percent of the first cost of the project, an amount presently estimated at $93,000. This local cost includes (1) an estimated $50,000 for furnishing all required lands, easements, and rights-of-way, (2) an estimated cost of $3,000 for relocation of utilities, and (3) a cash contribution presently estimated at $40,000. Additional data, including a breakdown of quantities and unit prices, are contained in Appendix E.

TABLE 5

FIRST COST AND ANNUAL COSTS
(1960 Price Level)

HURRICANE PROTECTION PLAN FOR COMPO BEACH AREA

Westport, Connecticut

Item	Federal	Local	Total
	First Cost and Project Cost		
Construction of Dike and Appurtenant Works	$217,000	$ 40,000	$257,000
Relocation of Utilities	-	3,000	3,000
Lands and Damages	-	50,000	50,000
Total First Cost	$217,000	$ 93,000(1)	$310,000
Preauthorization Studies	10,000	-	10,000
Total Project Costs	$227,000	$ 93,000	$320,000
	Annual Costs		
Interest(2)	$ 6,000	$ 3,300	$ 9,300
Amortization (50 years)	2,300	700	3,000
Maintenance and Operation	-	3,000(3)	3,000
Total Annual Costs (Financial Costs)	$ 8,300	$ 7,000	$ 15,300
Adjusted Annual Costs (Economic Costs)	$ 8,300	$ 7,900(4)	$ 16,200

(1) 30% of total first cost of $310,000.
(2) Federal at 2.625%, local at 3.5%.
(3) Includes allowances for major repairs.
(4) Adjustment for difference between 5.5% land rate interest and 3.5% local interest rate, on land value of $45,000, adds $900 of interest for economic costs.

ESTIMATES OF BENEFITS

69. The average annual benefits creditable to the local protection plan for the Compo Beach area, from the prevention of tidal-flood damages, are estimated at $39,300. This amount equals the difference between a total average annual loss of $41,300 in the protected area, below the design elevation of 10.5 feet msl, before protection, and an average annual residual loss of $2,000 remaining after protection is provided. The residual loss represents damages from fresh water ponding behind the protection during periods when the outlets through the dikes are closed. Damages from tidal flooding begin at a flood stage of approximately 7.0 feet msl.

There are no indications of any benefits to be realized from a reduction in emergency costs incurred upon receipt of a hurricane warning or from the enhancement of land values. Flooding of the area in the past has been a nuisance to property owners but has not presented any serious threat to life. Insecurity and worry among the residents concerning unpredictable hurricane tidal flooding would be greatly reduced by construction of the project. However, the threat of flooding above the record level experienced in 1938, although of infrequent occurrence, would be ever present.

ECONOMIC JUSTIFICATION

70. A comparison of economic annual costs of $16,200 with evaluated annual benefits in an amount of $39,300 gives a benefit-cost ratio of 2.4 to 1.0 for the selected plan of protection. The prevention of flood damages in one recurrence of a hurricane of September 1938 magnitude would amount to $290,000 and would practically repay the first cost of the project.

PROPOSED LOCAL COOPERATION

71. The protection plan for Westport is a project for local protection against hurricane-induced tidal flooding. On this basis, in line with the cooperation established in connection with authorized hurricane protection projects at other localities, local interests would be required to participate to the following extent:

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for construction and subsequent maintenance of the project at a presently estimated cost of $50,000.

b. Accomplish the modification or relocation of all buildings and utilities made necessary by reason of construction of the project at a presently estimated cost of $3,000.

c. Contribute in cash an amount presently estimated at $40,000, equal to 30 percent of the first cost of the project, with credit allowed for the costs incurred in fulfilling local cooperation requirements a and b above.

d. Hold and save the United States free from damage due to the construction works.

e. Maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of the Army. The annual cost of operation and maintenance to be provided by local interests, including allowance for major repairs, is estimated at $3,000.

No definite offers of cooperation were advanced by local interests at the public hearing held 31 March 1960. They did indicate an awareness of the fact that cooperation would be required. No objections were voiced. Subsequent to the hearing, expressions of willingness and ability to comply with the above provisions of local cooperation have been received from responsible elected officials of Westport and the State of Connecticut. See Appendix F.

APPORTIONMENT OF COSTS AMONG INTERESTS

72. A breakdown of the total first cost and annual charges for hurricane protection at Westport, Connecticut, between Federal and non-Federal interests, is shown in Table 5. The figures in this table are predicated on local cooperation to the extent set forth in paragraph 71 above, with local interests making a cash contribution to the first cost.

The first cost of the project is estimated at $310,000. The total first cost to local interests is estimated at $93,000 which includes $50,000 for the acquisition of lands and rights-of-way, $3,000 for relocating utilities, and a cash contribution in an amount of $40,000. The Federal first cost is presently estimated at $217,000.

The total annual costs (financial) for the project are estimated at $15,300. The Federal portion is $8,300 and the local share $7,000, or about 46 percent of the total.

COORDINATION WITH OTHER AGENCIES

73. In the course of this survey, assistance and cooperation have been received from Federal, state, and local agencies that are concerned with hurricane activities, or are particularly interested in the hurricane protection problem at Westport. Meetings have been held with representatives of these agencies for the purposes of discussing the proposed plans of protection and alternative plans, determining the effect of the plan on other interests concerned with development and use of the water and other natural resources of the locality, and ascertaining the relationship between the proposed hurrican protection plan and the plans of other agencies for improvements within the survey area.

The U.S. Weather Bureau has furnished information on the behavior and characteristics of hurricanes and data on maximum wind velocities and durations that may be anticipated in the future. The effect of the proposed dike protection on pollution has been considered by the Public Health Service of the U.S. Department of Health, Education and Welfare and the Connecticut State Water Resources Commission. These two agencies concur in the opinion that the plan would have no adverse effect on present sanitary conditions in the area. The Fish and Wildlife Service of the U.S. Department of the Interior and the Connecticut State Board of Fisheries and Game have also considered the plan and state that it would not have an adverse effect on the fish and wildlife resources of the area.

Informal meetings and conferences have been held with municipal officials of Westport and representatives of residents of the Compo Beach area to obtain their views and comments on the proposed plan and other plans that have been given consideration, also to keep local interests advised of the progress being made on the survey. Considerable assistance has been rendered by Town officials.

DISCUSSION

74. THE PROBLEM

The town of Westport has experienced heavy tidal-flood losses in recent hurricanes and other great storms. The cities and towns along the Connecticut coast, including Westport, although not situated on the open ocean, are subject to flooding from hurricane surges that travel up Long Island Sound from its eastern entrance off Montauk, Long Island. With a rise in water level caused by hurricanes or other storms, large areas along the coast of Westport involving relatively extensive lengths of shoreline are subject to tidal inundation. A Standard Project Hurricane, representative of future potential attacks, derived by transposing the 1944 hurricane, a storm of unusual energy off Cape Hatteras, to a track entirely over water, would create a surge of 9.2 feet at the mouth of the Saugatuck River at Westport, a surge that is approximately 20 percent greater than the 7.5-foot surge experienced in 1938. The occurrence of this project hurricane surge of 9.2 feet coincident with a tide at 1.3 feet msl would cause tidal flooding to an elevation of 10.5 feet msl, the record stage experienced in the 1938 hurricane. Protection to this flood level is the minimum degree of protection that should be considered for the flooded areas of the town. A recurring September 1938 hurricane would cause tidal-flood losses in Westport of approximately $1,400,000; a recurring September 1944 hurricane, losses of $540,000; and a recurring 1954 hurricane, losses of $1,070,000. Future storms, other than hurricanes, equal in severity to those experienced in November 1950 and November 1953, would cause damages in several sections of the town.

75. ALTERNATIVE SOLUTIONS

Some reduction in hurricane tidal-flood damages can be effected by the provision of improved forecasting and warning services, the establishment of programs for the evacuation of danger areas, the enactment of revised zoning ordinances, and the adoption of modified building codes. Improved warning facilities and plans for evacuation, although effective in reducing loss of life and damage to items which are readily movable, do not prevent the actual flooding of properties and are of relatively little value in preventing damage. Positive means of protection which would eliminate or minimize the threat of future flooding to existing properties are desirable wherever economically feasible.

76. SELECTION OF PLAN

A number of hurricane protection plans for Westport were considered. They included the following:

a. Saugatuck River. Two plans, each calling for a barrier across the river, were considered. One provided for a barrier at the mouth of the river and the other for a barrier about 3.3 miles upstream. Both of the barrier plans were found to be uneconomical.

b. Greens Farms area. Considered protection in this area, where the damage was principally to privately owned seawalls, consisted of sandfill to retard erosion. This protection was considered to be more in the nature of beach erosion control than hurricane protection. Moreover, Town officials have indicated that a protection plan for this area would not be locally supported. They consider this an improvement to be accomplished by private interests.

c. Saugatuck Shores. Dike protection, encricling this area of Westport at the mouth of the Saugatuck River, was found to be uneconomical.

d. Business District (East Bank). Dike and wall protection of the main business district of the town, on the east bank of the Saugatuck River, against a recurring 1938 flood stage is not economically justified but an economically justified project can be obtained by increasing the degree of protection. However, local interests have evidenced no particular desire for protection of this area and have indicated that any protection, to be acceptable, would have to be limited to that required to prevent flooding in the event of a 1938 flood stage.

e. Business District (West Bank). Dike and wall protection along the west bank of the river, above and below State Street, cannot be economically justified by the benefits derived from the prevention of tidal-flood damages.

f. Compo Beach area. Dike protection to residential properties in the Compo Beach area bounded by Compo Road South, Compo Beach Road, and Soundview Drive, to an elevation of 10.5 feet msl, as experienced in 1938, is economically justified and is the selected plan of protection for Westport. This is protection to a tidal-flood

stage that has a frequency of occurrence of approximately once in a 50-year period. Increasing the degree of protection by raising the height of the dike results in incurring additional costs that exceed the additional benefits that are secured.

Protection to a flood stage of 12.5 feet msl, two feet higher than the design flood elevation of 10.5 feet msl, results in total benefits that exceed the total cost. Protection to this stage of 12.5 feet msl, which has a frequency of occurrence of approximately once in 275 years, would be desirable in the interest of increasing safety and minimizing the false sense of security that protection of a lower degree might well engender. However, local interests have indicated that local support for a project of this degree would not be forthcoming. Their desire is for protection limited by the 1938 experienced flood level of 10.5 feet msl.

Additional information on the recommended and alternative projects called for by Senate Resolution 148, 85th Congress, 1st session, adopted 28 January 1958, is contained in Attachment I to this report.

77. EFFECT ON OTHER INTERESTS

The proposed project would have no adverse effects on fish and wildlife, pollution control, recreation, or other interests. The dike would be constructed in large part on town-owned land and would not adversely affect present or future land uses in the general area.

78. COSTS

The first cost of the project, including lands, easements, and rights-of-way, and relocation of utilities, is estimated at $310,000. The annual charges (financial) are estimated at $15,300; the annual costs (economic) at $16,200.

79. BENEFITS

The net average annual benefits to be obtained from the protection, from the elimination of flood damages, are estimated at $39,300. The benefit-cost ratio of the project is 2.4 to 1.0.

CONCLUSIONS

80. Residential and commercial areas of Westport, along the shore of Long Island Sound and the banks of the Saugatuck River, have sustained serious damages in the past from tidal flooding caused by hurricane and other great storms and face the continuing threat of similar damages in the future. Protection by means of a barrier across the mouth of the Saugatuck River or upstream of the mouth is not feasible. The protection of seawalls and the grounds of private estates in the Greens Farms area by the placement of sandfill has some merit but lacks local support. This improvement appears to be more in the nature of a beach erosion improvement measure than a hurricane damage prevention project. Local protection for the Saugatuck Shores area, and the business district along the west bank of the Saugatuck River, above and below State Street, by the construction of dikes and walls, is not economically justified. Dike protection for the main business center of the town, on the east bank of the Saugatuck River, to an elevation of 12.5 feet msl, is economically justified but is not desired by local interests. Protection of this area against flooding to a level of 10.5 feet msl, as experienced in 1938, would be acceptable to local interests but lacks economic justification. Protection of the residential area in the Compo Beach section of the town against flooding to a stage of 12.5 feet msl, or two feet above the 1938 level, can be provided at a cost that is exceeded by benefits. This would afford a desirable degree of protection but is not acceptable to the local people. They desire a project providing protection in this area against a flood stage no higher than the experienced 1938 level of 10.5 feet msl. It is concluded that protection of this residential area, against a recurring 1938 flood stage, can be attained through the construction of a protective dike at a total first cost of $310,000. This protection plan has a benefit to cost ratio of 2.4 to 1.0. It should be noted, however, that the storm surge in a Standard Project Hurricane, occurring coincident with a mean spring tide, would cause flooding to 13.6 feet msl which would overtop the protection and cause serious damages. It is reasonable to anticipate that the project would be overtopped at least once in its estimated 50-year economic life by a tidal-flood stage above the experienced 1938 level of 10.5 feet msl.

RECOMMENDATIONS

81. It is recommended that a plan of dike protection for the Compo Beach area of Westport, Connecticut, against a recurring 1938 tidal-flood level of 10.5 feet msl, be authorized for construction. The presently estimated first cost to the United States is $217,000, and the annual cost $8,600.

It is further recommended that the project be authorized subject to the conditions that local interests cooperate to the following extent:

a. Provide all lands, easements, and rights-of-way necessary for the construction and the subsequent maintenance of the project, the costs incurred to be credited to the required local cash contribution to the project first cost.

b. Hold and save the United States free from damages due to the construction works.

c. Accomplish all changes, alterations, additions to, or relocations of any building and utilities made necessary by reason of construction of the project, the costs incurred to be credited to the required local cash contribution to the project first cost.

d. Operate and maintain all features of the project, after its completion, in accordance with regulations prescribed by the Secretary of the Army.

e. Contribute in cash an amount, presently estimated at $40,000, equal to 30 percent of the first cost with credit allowed for the costs incurred in fulfilling local cooperation requirements "a" and "c" above.

Incls-2
1. Plate 1-General Plan
   File No. WC-1-1000
2. Plate 2-Protection Plan
   File No. WC-1-1001

SEYMOUR A. POTTER, JR.
Brigadier General, USA
Division Engineer

GLOSSARY

HURRICANE SURGE: the mass of water causing an increase in elevation of the water surface above predicted astronomical tide at the time of a hurricane; it includes wind setup; sometimes the maximum increase in elevation is referred to as the surge.

HURRICANE TIDE: the rise and fall of the water surface during a hurricane, exclusive of wave action.

KNOT: a velocity equal to one nautical mile (6080.2 ft.) per hour (about 1.15 statute miles per hour).

OVERTOPPING: that portion of the wave runup which goes over the top of a protective structure.

PONDING: the storage of water behind a dike or wall from local runoff and/or overtopping by waves.

RUNUP: the rush of water up the face of a structure on the breaking of a wave. The height of runup is measured from the stillwater level.

SIGNIFICANT WAVE: a statistical term denoting waves with the average height and period of the one-third highest waves of a given wave train.

SPRING TIDE: a tide that occurs at or near the time of new and full moon and which rises highest and falls lowest from the mean level.

STILLWATER LEVEL: the elevation of the water surface if all wave action were to cease.

STORM SURGE: same as "hurricane surge."

GLOSSARY (Cont.)

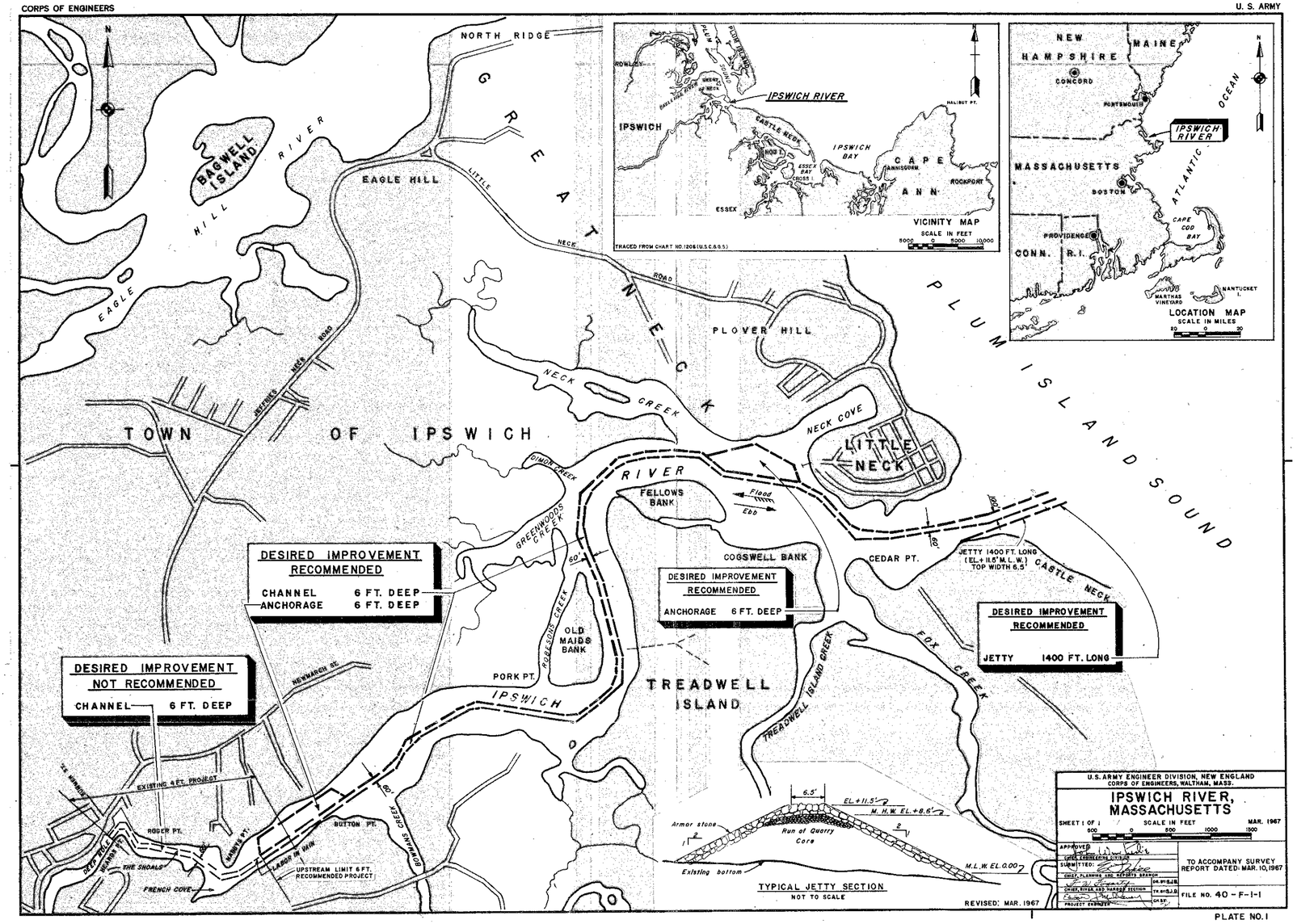
WAVE HEIGHT: the vertical distance between the crest and preceding trough.

WAVE TRAIN: a series of waves from the same direction.

WIND SETUP: the vertical rise in the stillwater level on the leeward side of a body of water caused by wind stresses on the surface of the water.

CORPS OF ENGINEERS

U. S. ARMY



U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

IPSWICH RIVER, MASSACHUSETTS

SHEET 1 OF 1 — SCALE IN FEET 500 0 500 1000 1500 — MAR. 1967

APPROVED:
CHIEF, PLANNING AND REPORTS BRANCH

SUBMITTED:
CHIEF, RIVER AND HARBOR SECTION
PROJECT ENGINEER

TO ACCOMPANY SURVEY REPORT DATED: MAR. 10, 1967

FILE No. 40 - F - 1 - 1

PLATE NO. 1

CORPS OF ENGINEERS

U. S. ARMY

GOLF COURSE

CUTTINGS LANE

13th HOLE GREEN

COMPO ROAD SOUTH

STA 0+00

STA 5+00

STA 10+00

STA 15+00

STA 20+00

RAMP

Minute Man Monument

GATED CONDUIT

DIKES

1938 HURRICANE FLOOD LINE EL. 10.5

COMPO BEACH ROAD

ROOSEVELT ROAD

APPLE TREE TRAIL

QUENTIN AVENUE

Historical Cemetery

GRAYS CREEK

FAIRFIELD AVE

BRADLEY STREET

DANBURY AVE

NORWALK AVE

WESTPORT AVE.

PARKING AREA

SOUNDVIEW DRIVE

SOUNDVIEW PLAZA

STA 25+00

STA 30+00

STA 33+00

STA 40+00

STA 45+00

CONC. WALL

GATED CONDUITS

AVERILL AVENUE

AGAWAM

YACHT BASIN

LONG ISLAND SOUND

MILLS POINT ROAD

STA 52+00

STA 55+00

EXISTING ROCK GROIN

LOCATION MAP

SCALE IN MILES

25 0 25 50

VERMONT

NEW HAMPSHIRE

MAINE

MANCHESTER

ALBANY

NEW YORK

MASSACHUSETTS

BOSTON

HARTFORD

CONNECTICUT

WESTPORT

PROVIDENCE

R.I

CAPE COD

NEW YORK

ATLANTIC OCEAN

SCALE IN FEET

100 50 0 100 200

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY	DR. BY	CK. BY
H.M.G.	R.J.C.	J.M.L.

SUBMITTED
CHIEF, HURRICANE UNIT NO. 2

PROJECT ENGINEER
A.H. Luptitt

APPROVAL RECOMMENDED
CHIEF, PLANNING BRANCH

APPROVED
CHIEF, ENGINEERING DIVISION

HURRICANE SURVEY
WESTPORT, CONNECTICUT
PROTECTION PLAN
COMPO BEACH AREA
GENERAL PLAN

DATE JUNE 1960

TO ACCOMPANY REPORT
DATED 31 MARCH 1961

SCALE: AS SHOWN

DRAWING NUMBER
WC - 1 - 1001

SHEET

PLATE 2

HURRICANE SURVEY

INTERIM REPORT

WESTPORT, CONNECTICUT

ATTACHMENT I

Additional information called for by
Senate Resolution 148, 85th Congress,
1st Session, Adopted 28 January 1958

U. S. Army Engineer Division, New England
Corps of Engineers, Waltham, Mass.

HURRICANE SURVEY

INTERIM REPORT ON
WESTPORT, CONNECTICUT

ATTACHMENT I

TABLE OF CONTENTS

TABLES

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

31 March 1961

ATTACHMENT I

to

INTERIM REPORT ON HURRICANE SURVEY
WESTPORT, CONNECTICUT

DATED 31 MARCH 1961

ADDITIONAL INFORMATION ON RECOMMENDED AND ALTERNATIVE PROJECTS CALLED FOR BY SENATE RESOLUTION 148, 85th CONGRESS, 1st SESSION ADOPTED 28 JANUARY 1958

1. INTRODUCTORY STATEMENT

The information in this supplement is furnished in response to Senate Resolution 148, 85th Congress, 1st Session, adopted 28 January 1958. This resolution requires information in addition to that now presented in support of projects recommended for authorization and on possible alternatives thereto. Reasons are given why alternatives are rejected in favor of the recommended project and the effects of alternative standards of evaluation, economic analysis, and cost allocation on project feasibility, scope, and cost-sharing arrangements.

2. PROJECT DESCRIPTION AND ECONOMIC LIFE

The recommended project provides dike protection to residential properties in the Compo Beach areas of Westport. The protection starts at high ground on the southwest side of Compo Hill, runs south along the east bank of Grays Creek, on the west side of Compo Beach Road, to Agawam Avenue, then easterly along the south side of Compo Beach Road to Soundview Drive, and then along the seaward side of Soundview Drive to its intersection with Compo Road South and Hills Point Road. The plan is described in further detail in paragraphs 60 to 63 of the report and in Appendix E.

The economic life of the project, used in the economic analysis in the report, is 50 years.

3. PROJECT COSTS

The estimates of first and annual costs have been prepared on the basis that local interests would (1) furnish all lands, easements, and rights-of-way necessary for construction of the project, and accomplish all necessary modifications to sewerage and drainage facilities and relocations of utilities and structures, (2) contribute in cash, towards the first cost of the project, an amount equivalent to 30 percent of the first cost of the project less credit for furnishing lands, easements, and rights-of-way and accomplishing necessary modifications to sewerage and drainage facilities and relocations, (3) operate and maintain all features of the project after completion.

Unit prices are based on averages for similar types of projects, either constructed, under construction, or under contract in New England and, where applicable, similar construction in other parts of the country, adjusted to 1960 price levels. Annual costs given in the report are based on 2.625 and 3.5 percent interest on the Federal and non-Federal investments, respectively, and amortization over a period of 50 years. Project costs and annual charges, based on a project life of 50 years and 100 years, are given in Table 1. Further details of project costs are given in paragraph 68 of the report and in Appendix E.

4. BENEFIT-COST RATIOS

Table 1 presents a summary of economic data for the recommended plan. The ratio of annual benefits to annual costs is given for both a 50-year and a 100-year project life.

Benefits are based on the same classification of tangible benefits as given in paragraph 69 of the report. Annual costs, consisting of interest on investment, amortization, and maintenance and operation costs, are based on the same classification of cost items as given in paragraph 68 of the report. Both financial annual costs and economic annual costs, which are used in determining the benefit to cost ratio, are given in Table 1.

The benefit to cost ratio based on a 100-year project life is approximately 15 percent greater than a ratio based on a 50-year project live.

5. INTANGIBLE PROJECT EFFECTS

Flooding of the residential area in the vicinity of Compo Beach has been a nuisance to property owners but has not presented any serious threat to life. Construction of the project would greatly reduce the nuisance problem and the danger of disease arising from polluted floodwaters. Protection to the 1938 record level of flooding would tend to reduce the sense of insecurity and worry fostered by the possibilities of future hurricane tidal flooding and would improve the general welfare of the residents. The threat of flooding above the record level experienced in 1938, however, would not be eliminated.

6. PHYSICAL FEASIBILITY AND COST OF PROVIDING FOR FUTURE NEEDS

No needs other than the control of tidal flooding were anticipated to develop during the useful life of the project.

7. ALLOCATION OF COSTS

Since the recommended project would serve only to prevent hurricane-induced tidal flooding, no allocations of costs among purposes or interests are required.

8. EXTENT OF INTEREST IN PROJECT

The recommended plan received strong support from local interests at a public hearing held in Westport on 31 March 1960. The Governor of the State of Connecticut and the Selectmen of Westport have endorsed the plan. Copies of letters of endorsement are contained in Appendix F.

9. REPAYMENT SCHEDULES

There are no reimbursable features incorporated in the recommended plan. Any required cash contribution by non-Federal interests would be made prior to the initiation of construction.

10. EFFECT OF PROJECT ON STATE AND LOCAL GOVERNMENTS

The project would have little effect on state and local governments other than a small loss of taxes on privately-owned land required for the project. No allowance for the loss of taxes on land has been

included in the annual charges since much of the required land is publicly owned. The plan would undoubtedly result in increased tax revenues arising from increased values of properties that would be no longer subject to tidal flooding.

11. ALTERNATIVE PROJECTS

A number of alternative plans of protection in Westport were considered. Barriers across the Saugatuck River were found to be uneconomical. A study of a plan for the placement of sandfill forward of existing seawalls in the Greens Farms area of the town, to reduce wave attack and resulting damage, indicated that the costs of such a plan would approximate the benefits. The improvement is considered to be more in the nature of a beach erosion prevention measures with benefits resulting from the prevention of damage to privately owned walls. Local officials have informally indicated that Town support for this plan would be lacking. An investigation of the possibilities of providing dike protection for the residential area at Saugatuck Shores indicated that the cost would exceed the benefits. Dike or wall protection for the industrial and commercial area of the town on the west bank of the Saugatuck River, north and south of State Street, just below the head of tidewater, was also found to be unjustified. Protection for the main business district on the east bank of the Saugatuck River, against flooding to a stage 2.0 feet above the 1938 record level of flooding, is economically justified. It is the desire of local interests, however, that any protection in this area be limited in height to that required for protection against the record 1938 flood level. Protection of this latter degree is not economically justified. Further details on the plans considered and the selection of a plan of protection are included in paragraphs 58 and 59 of the report.

TABLE I

COMPARISON OF PROJECT COSTS AND BENEFITS
50-YEAR AND 100-YEAR ECONOMIC LIFE
(1960 Price Level)

HURRICANE PROTECTION PLAN

Westport, Connecticut

	50-Year	100-Year
Federal Investment		
Total Federal First Cost	$217,000	$217,000
Preauthorization Studies	10,000	10,000
Total Federal Investment	227,000	227,000
Federal Annual Costs		
Interest on Investment, 2.625%	6,000	6,000
Amortization	2,300	500
Total Federal Annual Costs	8,300	6,500
Non-Federal Investment		
Contributed Funds	40,000	40,000
Relocation of Utilities	3,000	3,000
Lands and Damages	50,000	50,000
Total non-Federal Investment	$ 93,000	$ 93,000

TABLE 1, Cont.

	50-Year	100-Year
Non-Federal Annual Costs		
Interest on Investment, 3.5%	$ 3,300(1)	$ 3,300(1)
Amortization	700	100
Maintenance and Operation	3,000	3,000
Total Non-Federal Annual Costs	$ 7,000	$ 6,400
Total Annual Costs (Financial)	$ 15,300	$ 12,900
Total Annual Costs (Economic)	$ 16,200(1)	$ 13,800(1)
Total Annual Benefits	$ 39,300	$ 39,300
Ratio of Annual Benefits to Annual Costs (Economic)	2.4 to 1.0	2.8 to 1.0

(1) Adjustment for difference between 5.5% land rate interest and 3.5% local interest rate, on land value of $45,000, adds $900 of interest for economic costs.